

THE LIMITATIONS OF COMPUTER MODELS INTENDED TO AID ENERGY EFFICIENT DESIGN OF BUILDINGS

Dr. R.H. BYRD Dip Arch, PhD R.I.B.A.

SYNOPSIS

My intention, in this paper, is to discuss the limitations of computer models that are intended to aid designers to produce more energy efficient buildings. The question I put forward is : to what extent will a typical building designer benefit from typical software that is available to him?

I would like to focus on the two main issues that limit the potential of computer models :

- 1) The accuracy of the models in simulating thermal performance,
- 2) Their ability to influence design decisions.

My conclusions are that these models offer little benefit to designers at the strategic design stages and that their accuracy is such that many simple rules-of-thumb may well be of greater benefit to designers.

1. Accuracy of Models

Firstly, I shall discuss the accuracy of simulation by looking at the most basic of models : the 'heat loss' calculation :

At this stage I should say that simulation models are by definition unfaithful to reality. Their advantage is that they can be run faster than reality but the penalty for this is a loss of accuracy.

Figure 1 lists the main variables and assumptions in a heat loss calculation. My intention is to quantify, albeit approximately, the accuracy of each part of the model.

- i) Air change rate by infiltration or ventilation is generally the largest component of heat loss. It may be typically 50% of the overall heat increasing to 75% in well insulated buildings. Despite tracer-gas and pressurisation techniques for measuring air infiltration there is no reliable assessment of air change rate in naturally ventilated buildings Ref 1. Indeed the idea of assigning one quantity to a very dynamic characteristic of a building is fraught with problems. Recommended values of whole house ventilation typically vary from 0.5 to 1.5 air changes per hour. It is quite possible that large errors could be made in guessing the air change rate. I shall conservatively assume errors in the order of + or - 50%.
- ii) Generally the rate of heat loss through glass is about 10 times greater than through the walls. (5.6 to 0.6 or 2.8 to 0.3). If a building has 20% of its elevations glazed then 80% of the elevational heat loss is through the glass. For single glazing, the 'U' value is usually assumed to be 5.6 w/sqm C of which the largest components are the internal and external surface resistances. The magnitude of these resistances is largely determined by air movement. For example, it has been shown (2)

that air movement due to a warm air heating system can increase the 'U' value of glazing in excess of 7w/sqm C.

- iii) Heat loss calculations normally assume that heat transfer from a building is by convection and conduction. It has been shown (3) that longwave radiation can account for between 10-40% of heat loss from the building fabric. It is very difficult to predict as it is proportional to the fourth power of the surface temperatures of a building and what it 'sees'. It is generally omitted from heat loss calculations.
- iv) Convective heat transfer from the building fabric ('U' values) varies considerably depending on moisture content and local air movement. It has been estimated (4) that the values given in the CIBSE guide vary by + or - 30%.
- v) In measuring the areas and thicknesses of building elements and components certain estimates are made. It has been calculated (5) that (for houses) taking the internal dimensions, and omitting floor zones the accuracy of the calculation could be underestimated by 15%. There are other assumptions made when 'measuring' a design: joists are typically 15% of the area of a ceiling, mortar is 7% the area of a lightweight blockwork wall, blockwork returned at reveals around openings is about 5% of the mass of wall area in housing, heat loss through floors is still based on the area of floors although most heat passes through the perimeter.
- vi) There are also theoretical assumptions about the nature of the flow of heat: in particular 'steady-state' heat loss. A useful analogy to illustrate this inaccuracy is to calculate the average speed of a car going 10 miles from A to B at 20mph and returning at 40 mph. It would seem to be a fair assumption to assume the average speed to be 30 mph although it is 26.6 mph. 'Steady-state' theory makes similar assumption about the rate of heat flow.

All these inaccuracies are concerned with the variables in the heat loss equation. Figure 1 indicates, conservatively, that the accumulated accuracy may be of the order of + or - 70%.

Added to this should be those variables that are almost impossible to quantify and yet have a very large effect on the overall variation between the predicted and actual heat loss. The two main factors are a) occupant interaction with the building (opening windows, closing curtains, altering heating regimes) and b) construction differences (building defects, gaps, cracks, defective materials etc.).

The combined effect of all these variables, assumptions, intervention and defects, could easily result in the accuracy of a computer model being + or - 100% accurate.

Of course different models will have addressed the above assumptions to different degrees and the author's will no doubt claim greater accuracy. However, in terms of predicting thermal performance, I have only discussed the 'heat loss' issues and not the many other assumptions that must be taken in order to predict energy consumption. For example, assumptions concerning

plant efficiencies throughout the year, heat gains from internal sources and the gross assumption that raw climatological data used in models represents the actual climatic stimuli on buildings.

So how do the author's of such software get away with it? Firstly, and most important, many of the errors cancel each other out. This has been described as 'a cacophony of cancelling errors'. (6) The many accumulated errors that could result in an accuracy of + or - 100% cancel each other out to an increased accuracy. Figure 2 compares the accuracy of several common models to each other with a resulting variation of + or - 20%. If compared to the 'actual' energy consumed, these models may well be less accurate still. But the important issue here is that the models tend to be more accurate than I have calculated not because of precision but because of luck.

Secondly, and particularly in housing, one may be excused for being impressed by the graphs that indicate how accurate the models are by comparing actual and predicted results. These results are based on averages. One only needs to look at the widespread of space heating energy consumption in identical houses (Figure 3) to see that the prediction could be wildly inaccurate for any individual house.

2. The use of models in the design process

Irrespective of the accuracy of models, what scope is there for computer models to improve the energy efficiency of designs?

Computer models of energy efficiency cannot be fed with the design brief and be expected to produce an energy efficient design. A design solution must first be generated and this must be done to a reasonable level of detail in order that the computer model can have enough information to 'accurately' evaluate the design.

This initial design solution must be done without access to the computer model. And hence the design has inherent in it many 'strategic' consequences concerning its thermal performance that have been made without the computer model. Having fed the design into the model, just as the model cannot 'generate' a design, neither can it redesign it. The computer model is concerned with refining only the detail of the design. The designer makes the 'strategic' decisions and the computer helps with the 'tactical' decisions. As computer models can give no guidance at the 'strategic' stages of design, they have only the capacity to try and make the best of what may be an intrinsically poor design.

An analogy of this is the tuning of an old radio. The designer, like the radio operator, has a 'coarse' (strategic) tuner and a fine (tactical) tuner. The wavelength/wave bands represent the limitless number of possibilities and to get good reception (good design) the designer must first use the coarse tuner and then the fine tuner. The problem is that much of energy-efficient design is carried out without a coarse tuner. Armed only with a fine tuner the designer has little scope to come up with a good strategic design solution, he can only try to make the best of a bad job.